

Astronomical Observing Techniques 2019:

Exercises on Detectors 2

(Due on 6 May 2019 at 11:00)

May 2, 2019

1 Aperture Photometry

- a) You plan to do accurate photometry of a 15th magnitude star in the V-band with the 4.2-meter diameter William Herschel Telescope. Assuming an overall efficiency of the atmosphere, the telescope, including the secondary obscuration, and the imaging system of 10%, what SNR could you reach if you integrated for 1000 seconds and assumed that the photon noise dominated all other noise sources? Hint: A 0-th magnitude star produces a flux of 9×10^9 photons/m²/s in the V-band.
- b) To obtain accurate photometry of the 15th magnitude star during the bright time that was allocated to you, you need to subtract the sky background, which is expected to be 17.5 magnitudes per arcsec squared in the V-band. Assuming that your central circular area containing the star has a radius of 1.8 arcsec and that you measure the sky background in a ring that has the same area as your central area, what is the maximum SNR that you can achieve after removing the sky background?

2 Reducing the Dark current

At room temperature, a CCD can be problematic due to the dark current. For certain scientific CCDs the dark current can saturate the detector in a few seconds making it impossible to image faint objects. The lower the temperature of a CCD, the less dark current. The Fermi distribution provides an estimation for the number of electrons per second accumulate in a semiconductor pixel:

$$\frac{dN_D}{dt} = A_0 T^{3/2} e^{-\frac{E_G}{2kT}} \quad (1)$$

with T being the temperature, A_0 is a constant that depends on pixel parameters, and E_G is the bandgap energy. Assume the bandgap energy varies with operating temperature according to the empirical formula:

$$E_G[\text{eV}] = 1.1557 - 7.021 \times 10^{-4} \frac{(T[\text{K}])^2}{1108 + T[\text{K}]} \quad (2)$$

At an operating temperature of 300K, a certain CCD has a dark current of 10^5 electrons per second.

- a) Compute the dark current, in electrons per second, if this CCD is operated at 233 K (-40° C).
- b) Estimate the operating temperature at which the dark current will be 10 electrons per second. Assume that the difference in band-gap energy at different temperature is negligible.

3 X-ray CCD Camera

An X-ray CCD camera on a satellite observes a constant X-ray source for 30 minutes. Every minute, the camera takes 2 exposures of 25 seconds. The remaining time is used to read out the CCD. During the whole observation, a total of 720 X-ray photons hit the surface of the CCD detector. How many exposures can we expect with less than 3 photons?